Supporting Active Learning in an Undergraduate Geotechnical Engineering Course using group based ARS quizzes

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Abstract
The use of Audience Response Systems (ARS) or "clickers" in higher education has increased over recent years, predominantly owing to their ability to actively engage students, for promoting individual and group learning, and for providing instantaneous feedback to students and teachers. This paper describes how group-based ARS quizzes have been integrated into an undergraduate civil engineering course on foundation design. Overall, the ARS summary quizzes were very well received by the students. Feedback obtained from the students indicates that the majority believed the group based quizzes were useful activities, which helped to improve their understanding of course materials, encouraged self-assessment and assisted preparation for their summative examination. Providing students with clickers does not, however, necessarily guarantee the class will be engaged with the activity. If an ARS activity is to be successful, careful planning and design must be carried out and modifications adopted where necessary, which should be informed by the literature and relevant student feedback.

Keywords: active learning, clickers, civil engineering, peer interaction

1. Introduction

Active learning enhances understanding and longer lasting memory retention (Bligh 1998; Felder and Brent 2003). Shuell (1986) suggested that if students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to "engage in learning activities that are likely to result in their achieving those outcomes". Entwhistle (1997) suggested that this fundamental task involves encouraging students to adopt a deeper approach to learning, where students think critically and interact actively with the information they receive rather than accepting it passively and simply reproducing it during assessment. In an engineering learning environment, students may be exposed to a wide range of methods aimed at stimulating active learning, some examples of which include problem-based learning (Huntzinger et al. 2007; Hansa 2008; Gavin 2011), real world demonstrations (Shapira 2005; Todd et al. 2005; Ashford and Mills 2006), design projects (McAlpine et al 2006; Dowlen and Townsend 2011) and virtual experiments (Kajewski 1999; Vera et al, 2006; Shekar 2007).

The use of handheld, wireless Audience Response System (ARS) devices (also called electronic voting systems, classroom communication systems or simply "clickers") in higher education has increased over recent years, predominantly owing to their ability to actively engage students, for promoting individual and group learning, and for providing instantaneous feedback to students and teachers (Nicol and Boyle 2003; Reay et al. 2008; Davenport et al. 2009; Schmidt 2011). Students are supplied with a clicker and use them to select answers to multiple choice questions. This information is then gathered wirelessly (or wired) by a computer and the distribution of resultant answers can be instantly displayed on screen for review and discussed with the class.

This paper describes a case study based on the regular use of group based ARS quizzes for supporting active learning and peer interaction in an undergraduate civil engineering course. A review of relevant higher education case studies involving ARS is firstly carried out. The design of the ARS activities is then described in detail and subsequent feedback from students is discussed.

2. Audience Response Systems

A large number of authors have recently discussed the benefits and limitations of using Audience Response Systems in higher education (e.g. Nicol and Boyle 2003; Fies and Marshall 2006; Caldwell 2007; Davenport et al. 2009; Bashforth and Parmar 2010; Schmidt 2011). Davenport et al. (2009), for example, suggested a number of ways in which ARS could be used to support student learning, such as (1) for diagnostic assessment at the beginning of a lecture, (2) for monitoring understanding of the context by students, (3) for enabling the provision of immediate feedback within the context, (4) for keeping students actively engaged in their learning and (5) for promoting peer interaction and support. Diagnostic assessment at the beginning of a lecture refers to the use of ARS as a tool for assessing student's prior knowledge of a subject or even for checking attendance (Bashforth and Parmar 2010). Guthrie (2004) observed that understanding is significantly improved when students received corrective feedback for incorrect answers. This was also discussed by Kulik and Kulik (1988) who discussed the positive impact that immediate feedback may have on student learning. The importance of formative feedback was also highlighted by Biggs and Tang (2007) who suggested that "the effectiveness of different teaching methods is directly related to their ability to provide formative feedback". In terms of a direct link to improved academic performance, Fang (2009) observed a strong relationship between success in clicker quizzes and subsequent exam performance. In addition to providing feedback to the student, ARS may also provide valuable feedback to the lecturer as the responses from the students may be collected and subsequently analysed in order to identify areas of a course which may need further attention.

ARS has also been used by some authors for supporting and improving peer interaction between students (Nicol and Boyle 2003; Schmidt 2011). Nicol and Boyle (2003), for example, reported that students found it easier to understand difficult concepts, when explained by a peer. They suggested that peer discussion leads to points of agreement and disagreement, leading to students challenging and justifying different points of view, which "results in students jointly negotiating or constructing an improved conceptualisation based on a reconciliation of their different interpretations". In short, it encourages a deeper approach to learning. Schmidt (2011) observed that peer interaction during ARS classes resulted in students having a better conceptual understanding of the subject being taught (engineering dynamics). This study also indicated that peer interaction in this manner can improve a student's ability to self-assess and critically analyse problems. A number of authors have also argued that ARS can be very supportive of student learning if used with large class sizes (Nicol and Boyle 2003; Caldwell 2007; Bashforth and Parmar 2010). In large classes students may not have an opportunity or may not feel comfortable contributing to oral, class-wide discussion. In contrast to this, ARS activities afford the opportunity for all students to anonymously contribute an answer to each question posed. Also, the study of Nicol and Boyle (2003) suggested that with increasing numbers of students, class-wide discussion becomes progressively more difficult for teachers to manage. They observed that peer instruction using ARS is relatively easy to manage, even with large class sizes.

Guthrie (2004) pointed out that ARS technology incorporates several concepts within which the modern student is familiar, notably the inclusion of ubiquitous technologies, the sense of social networking and interaction, and the instant visual reward for participation. They suggested that ARS may provide the lecturer with a means of engaging the students that fits with the current technologically saturated culture.

In terms of potential limitations of ARS activities, Trees and Jackson (2007) and Draper and Brown (2002) reported that some students were distracted and others were disengaged from clicker activities. Trees and Jackson (2007) recommend that students should be informed of the relevance of the activity for their learning at the outset. They suggested that the success of clickers depends less on the teacher and more on the students' willingness to accept and use them. Clearly, however, it is the role of the teacher to design interesting activities that are stimulating for the student cohort. If the activities are to be successful, careful planning and design must be carried out and informed by best practice, as discussed in the literature.

3. Design and integration of ARS quizzes into a course on foundation design

The use of ARS for supporting active learning and peer interaction was trialed on a second year Civil Engineering course (Foundation Design) at the University of Bath. Although the students had some prior knowledge of soil mechanics, this course represents their first engagement with the more practical elements of geotechnical engineering. Although the class size was relatively large, with an average of 74 students in attendance, as discussed above, a number of authors have demonstrated the benefits of using ARS with large groups (Nicol and Boyle 2003; Caldwell 2007; Bashforth and Parmar 2010). It was therefore decided to trial the ARS system, by incorporating a number of summary quizzes into the course. The overall aims of the trial were (i) to provide an enjoyable means of summarising different parts of the course, (ii) to develop understanding throughout the course by providing regular formative feedback to the students, (iii) to encourage students to self-assess their understanding of the course materials and (iv) to promote active learning via peer interaction between the students.

The foundation design course, at the University of Bath, is taught in three individual sub-sections, site investigation (weeks 1-3), shallow foundations (weeks 4-7) and deep foundations (weeks 8-11). In order to develop understanding throughout the course, in the last lecture of each section, an hour long ARS quiz was conducted. Providing regular feedback to students was recommended by Taylor (2008), who pointed out that "Early assessments are important for novice students to ensure that engagement is encouraged and feedback provided early". Although they are not quite novice students, being in their 2nd year, this is the first time that they will have encountered the practical side to geotechnical engineering and so may be considered novices with regard to their prior understanding. Taylor (2008), recommended that in the early stages of a course, assessments providing formative feedback should be relatively easy and as the course proceeds should be designed to get progressively more difficult. Taylor suggested that during the final weeks of a course, formative assessments should be more challenging and aimed at preparation for summative assessments. Taking this into account, each ARS quiz was designed to be a little more challenging than the previous one in order to assist student preparation for final assessment.

At the outset, it was decided that in order to encourage peer interaction between students, the class would be divided into groups of around 6 students, with only one clicker provided to each group. As a result, students needed to work together in order to formulate a collective answer to a question posed. This is, of course, different to the majority of cases discussed in the literature where clickers are provided to individuals, rather than to a group of students. Discussions with other teachers, experienced in the use of ARS, suggested that when all students are each provided with a clicker, the level of interest and peer interaction reduces as an activity progresses. It was observed, however, at an early stage, that when large groups of more than 7 students were assembled, students on the periphery of the groups appeared to rapidly lose interest as they were not always able to interact with the group discussion. Also, it was felt that groups of 2 or 3 students would be at a significant disadvantage when it came to pooling their knowledge and understanding for answering the questions. It was therefore decided that for all quizzes, each of the groups would have a minimum of 4 and a maximum of 6 students. The division of the class into groups or teams brought about a lively and mildly competitive atmosphere in which each of the groups really wanted to win the quiz. To avoid a simple test of memory and encourage the development of understanding, students were also allowed to consult their notes during the quizzes.

As recommended by Trees and Jackson (2007), before each quiz commenced the class was informed of the learning outcomes of the activity and the importance of their participation. Two dummy questions were also posed before the start of the quiz, in order to ensure that that all clickers were functioning properly and to confirm that the overall system of data collection and presentation was working correctly.

Following the activity, the university's Virtual Learning Environment (VLE) was used for providing formative feedback to students by placing all quiz questions and answers and group results online.

3.1. *Designing questions & answers*

When creating interactive multiple choice quizzes, with the aim of developing understanding, the most challenging aspect from the lecturers' point of view involves the design of appropriate questions and the selection of suitable answers. Rhem (2009) discusses design of questions for interactive quizzes and suggests that although multiple choice questions are generally thought to only encourage factual recall, questions can be designed to have "really good wrong answers", where students must think about the validity of each before choosing what they perceive to be the most likely answer. A maximum of five possible answers were provided in the present study, for each question, although the majority of questions contained only 3 or 4 answers. In total, the students were posed 13 questions during the summary quiz (not including the 2 initial dummy questions), of varying levels of difficulty. Although there was some variability in the length of time it took to complete the quiz, it was found that 13 questions was a suitable number which enabled the quiz to be completed within the one hour lecture period.

In order to maintain the students' interest and to test a variety of different skills, it was decided to design a range of questions of different styles, including arithmetic problem solving, logical reasoning, spatial aptitude, visual identification of images and other questions which tested the students understanding of various geotechnical concepts, introduced previously in the lecture series. As students were allowed to use their notes during the quizzes, it was important to design questions that both encouraged revision of course materials but also tested and developed understanding of these materials. At the start of each quiz the first three questions were not designed to be too taxing, with the correct answer relatively obvious. In addition to providing students with an opportunity to familiarize themselves with the format of the quiz, this was also intended to encourage all students to participate, regardless of their relative academic ability. With one or two exceptions, these questions were almost always answered correctly. Following these basic questions, the level of difficulty of the quiz questions was increased in a staged manner, with questions 4-8 designed to be at an intermediate level of difficulty and questions 9-13 designed to be the most challenging. Intermediate level questions were a little more difficult than the basic questions and of the possible answers provided, generally contained only two plausible solutions. In the more challenging questions, the teams had to work out the most likely answer from three or four very plausible solutions. An example question from each level of difficulty is presented in Figure 1.

A maximum time of five minutes was allocated for the teams to answer each of the questions, and if the majority of teams answered quickly, a 10 second countdown was given to the final two teams who had yet to provide an answer. In general, the questions were usually answered within 2-3 minutes.

3.2. *Answers & team results*

After all teams had provided an answer, a poll was displayed on the screen which indicated the percentage of groups who selected a particular response. In the first quiz, a number of students requested that the answers be explained more thoroughly to the class. As a result of this feedback, after the poll of selected answers was displayed (but before the correct answer was highlighted), the merits, or otherwise, of each chosen answer was discussed with the class. If an appropriate visual aid was available, this was used to demonstrate the validity of the correct answer to the class. Also, although the class size was relatively large, and the competitive element to the quiz created a lively atmosphere, as the groups discussed and debated the possible answers, it was found that due to the high level of interest the activity was easy to manage. When the answers were being discussed, the students were highly attentive and curious about why their chosen answer was correct or incorrect.

In order to provide regular feedback to the groups on their performance and relative ranking relative to the other groups, a scoreboard was displayed on the screen after every five questions. If there was a tie at the end of the quiz between two or more groups, and this happened on a number of occasions, a tiebreaker was performed for the relevant groups. Tiebreaker questions were intended as a light-hearted conclusion to the quiz. As such, these questions were relatively easy and the overall winner was decided by the group who responded quickest with the correct answer, using the clicker.

4. Effectiveness of the ARS activities

4.1 *Student feedback*

Following their final summative exams, feedback was sought from the students to obtain their impressions of the ARS activities. They were posed eight multiple choice questions and were asked to provide additional comments on their responses. Using a five-point scale, students indicated their agreement with each statement (i.e 1 = strongly negative response and 5 = strongly positive response to the question posed). All responses were gathered via an online survey.

The first four questions related to the student's perceptions on the usefulness of the quiz (Table 1). In general, the feedback received for these survey questions indicates that the students deemed the exercises to be of considerable valuable. In particular, the responses to Questions 1 and 2 indicate that the majority of students believed that the quizzes were useful activities, which helped to improve their understanding of course materials and encouraged self-assessment. Some comments from students that were associated with these questions included "Really helped consolidate knowledge", "They were very useful in terms of understanding the chapters – point out the key points", and "allow you to realise potential weak points". A similar observation was also made by Schmidt (2011), who observed that students who participated in clicker induced peer interaction were better at self-assessing and were more critically aware than students who were not involved in the activity. Of the few respondents who did not find the exercises particularly useful, some indicated that more content could have been covered in the quizzes, which would have been useful in preparing for the exams and suggested that "it would be helpful if they were assessed so that no guessing occurs and we would follow the content more closely". Although it may be worth considering incorporating a summative element to the summary quizzes, this suggestion is in contrast to a large number of students who indicated that they appreciated the formative feedback they had received from the quiz. In fact, the responses to Question 3 imply that the majority of students found that the quizzes actually assisted their preparation for their final summative examination. Student comments such as "constantly revising throughout the term provided recaps, so it was not all crammed in revision week" and "End of section quizzes made me refresh my knowledge during the semester and when exams came I was surprisingly stronger than in every other module" supported this view.

Also, although it appears that a majority of students thought that the quizzes improved their interest in foundation design, the mean result for this question (Question 4) was less than any other question posed. Example student comments related to this question included: "The course is generally quite interesting, the quizzes don't really boost the interest" and "the quizzes really sparked my enthusiasm for the subject matter."

In the questionnaire students were also asked two questions relating to their participation in the quiz and their level of interaction with their peers (Table 2). The feedback received indicated that the format of the quizzes encouraged general participation and, in particular, a very high level of peer interaction. One of the students suggested that the quiz format "gave everyone a way to express their own ideas and answers without being embarrassed or under pressure" with another suggesting that it was "useful to bounce ideas off my peers when answering the questions".

Finally, two further questions were posed to the students in the questionnaire (Table 3). As shown, from the responses to Question 7 the students found the level of difficulty of the quizzes to be reasonable, and if anything a little easy. One of the students suggested that "Some of the early questions were a little too easy, but they balanced out with some more challenging questions towards the end". The feedback, in general, indicates a progression in the level of difficulty of the quizzes, as originally intended.

Overall, the integration of the quizzes into the course appears to have been very well received by the students. This could partly be due to the attention devoted to the new activity by the teacher and the students. One of the primary reasons behind the success of the activity appears to be the introduction of a competitive element in the quiz ("competitive games are always fun"), with the majority of the students indicating that they liked being able to work together in groups and competing with opposing teams. In the last question (Question 8), students overwhelmingly agreed that the summary quizzes should be given a more permanent place in the course syllabus.

4.2 *Exam performance*

As shown in Table 4, the students' performance, in terms of mean result achieved, increased considerably when the quizzes were incorporated in the course when compared to the previous year where they had not been used. Analysis of Variance (ANOVA) carried out on the data indicates that the difference is significant ($p<0.01$). It should also be pointed out that the percentage of students receiving 1st class honours increased considerably and the failure rate (i.e. percentage of students receiving less than 40 %) also reduced by a substantial amount. A direct comparison between these datasets is not, however, straightforward, as some changes to the lecturing staff involved with teaching the course took place during this time. As a result, any direct conclusions made when comparing the student performance between the two years may be tenuous.

It should be pointed out, however, that the student responses to Question 3 (Table 1), which were received after the exam, suggested that the summary quizzes did strongly assist their exam preparation. This, perhaps, gives credence to the statistical data suggesting that the regular quizzes impacted positively on the students' performance.

5. Conclusions

This paper has described how ARS quizzes have been incorporated into an undergraduate civil engineering course on foundation design. Although others have suggested that one of the main benefits of the ARS technology is the ability to give every student the opportunity to contribute with their own clicker, in this study only one clicker was provided for each small group of students. Overall, the group based ARS summary quizzes were very well received by the vast majority of students. Although it is difficult to generalise from a single case study such as this, feedback obtained from the students indicated that the majority believed the group based quizzes were useful activities, which helped to improve their understanding of course materials, encouraged self-assessment and assisted their preparation for their summative examination. The feedback also indicated that the format of the quizzes encouraged general participation and, in particular, a very high level of peer interaction. The students also indicated that they enjoyed the competitive side to the quiz, and this definitely increased the level of interest in the activity. Although the class size was relatively large, and the competition between groups created a lively atmosphere, it was found that due to the high level of interest, the activity was easy to manage. As the merits of the different answers were being discussed with the students, the students were highly attentive and curious about why their chosen answer was correct or incorrect.

Overall, the integration of the ARS quizzes into the course is considered to have been a successful exercise in this instance and one that has met its original objectives. Providing students with clickers does not, however, necessarily guarantee the class will be engaged with the activity. If an ARS activity is to be successful, careful planning and design should be carried out and informed by best practice, as discussed in the literature. Relevant student comments may also provide an excellent source of feedback, upon which modifications to the activity can be based.

References

Ashford, P. and Mills, A., 2006. Evaluating the effectiveness of construction site visits as a learning experience for undergraduate students enrolled in a built environment course. In *Experience of Learning. Proceedings of the 15th Annual Teaching Learning Forum*, 1-2 February 2006. Perth: The University of Western Australia. Available from: http://lsn.curtin.edu.au/tlf/tlf2006/refereed/ashford.html [Accessed 19 July 2012].

Bashforth H., and Parmar N.R., 2010. The search for active learning: Lessons from a happy accident. Research Report. CSAP e-Learning Forum: sharing materials and practice in the social sciences: HEA Subject Network for Sociology, Anthropology, Politics. Available from: http://opus.bath.ac.uk/18900/2/Bashforth_Parmar_The_search_for_active_learning.pdf [Accessed 19 July 2012].

Biggs, J. and Tang, C., 2007. Teaching for Quality Learning at University (3rd edn), Open University Press.

Bligh, D., 1998. What's the Use of Lectures? (5th edition), Intellect Books.

Caldwell, J.E., 2007. Clickers in the Large Classroom: Current Research and Best Practice Tips. *Life Sciences Education*, 6, 9-20.

Davenport, J.H., Hayes A., Parmar N.R., 2009. The use of an Electronic Voting System to enhance student feedback. *Proceedings of: 4th Plymouth e-learning Conference: Boundary Changes: Redefining Learning Spaces*.

Dowlen, C. and Townsend, B., 2011. Doing engineering design: reflections on the active learning experience. *Proceedings of the 13th International Conference on Engineering and Product Design Education*, 11, 216-221.

Draper, S. W., and Brown, M. I., 2002. Use of the PRS (Personal Response System) handsets at Glasgow University, Interim Evaluation Report: March 2002. Available from: www.psy.gla.ac.uk/~steve/ilig/interim.html [Accessed 19 July 2012].

Entwistle, N., 1997. Contrasting Perspectives on Learning. In F. Marton, D. Hounsell and N. Entwistle (eds) *The Experience of Learning: Implications for Teaching and Studying in Higher Education*, 2nd edn. Edinburgh: Scottish Academic Press, 3-22.

Fang, N., 2009. Electronic classroom response system for an engineering dynamics course: student satisfaction and learning outcomes. *International Journal of Engineering Education*, 25 (5), 1059–1067.

Felder, R.M. and Brent, R., 2003. Learning by Doing, Chem. Engr. Education, 37(4), 282-283.

Fies, C. and Marshall, J., 2006. Classroom response systems: a review of the literature. *Journal of Science Education and Technology*, 15, 101–109.

Gavin, K. 2011. Case study of a project-based learning course in civil engineering design. *European Journal of Engineering Education*, 36 (6), 547-558.

Guthrie, W and Carlin, A., 2004. Waking the Dead:Using interactive technology to engage passive listeners in the classroom. *Proceedings of the Tenth Americas Conference on Information Systems,* New York, New York, August 2004.

Hasna AM. (2008). Problem Based Learning in Engineering Design, *Proceedings of SEFI 36TH Annual Conference, European Society for Engineering Education*. Available from: http://www.sefi.be/wp-content/abstracts/1146.pdf [Accessed 19 July 2012].

Huntzinger, D. N., Hutchins, M. J., Gierke, J.S. and Sutherland, J.W., 2007. Enabling sustainable thinking in undergraduate engineering education. International Journal of Engineering Education, 23(2), 218-230.

Kajewski, S., 1999. Virtual construction site visits via the world wide web. In K. Chen (Ed), *Australian University Building Educators Association Conference. Proceeding of the 3rd and 4th electronic conference,* 125-129.

Kulik, J.A., and Kulik, C.L.C., 1988. Timing of feedback and verbal learning. *Review of Educational Research*, 58, 79-97.

McAlpine, I., Reidsema, C., and Allen, B., 2006. Educational design and online support for an innovative project-based course in engineering design. In L. Markauskaite, P. Goodyear, and P. Reimann (Eds.) *Proceedings of the 23rd annual conference of the Australasian Society for Computers in Learning in Tertiary Education: Who's learning? Whose technology?* (497-507). Sydney: Sydney University Press.

Nicol, D.J. and Boyle, J.T., 2003. Peer Instruction versus Class-wide Discussion in Large Classes: a comparison of two interaction methods in the wired classroom. *Studies in Higher Education*, 28(4), 457-473.

Reay, N.W., Li, P. and Bao, L., 2008. Testing a new voting machine question methodology. *American Journal of Physics*, 76, 171–178.

Rhem, J., 2009. Clickers, *National Teaching and Learning Forum Newsletter*, 18 (3). Available from: http://cgi.stanford.edu/~dept-ctl/cgi-bin/tomprof/posting.php?ID=950 [Accessed 19 July 2012].

Schmidt, B. 2011. Teaching engineering dynamics by use of peer instruction supported by an audience response system. *European Journal of Engineering Education*, 35 (5), 413-425.

Shapira, A., 1995. Bringing the site into the classroom: a construction engineering laboratory, *Journal of Engineering Education*, ASEE, 84(1), 81-85.

Shekar, A., 2007. Active learning and reflection in product development engineering education. *European Journal of Engineering Education*, 32, 125–133.

Shuell, T.J., 1986. Cognitive conceptions of learning. *Review of Educational Research*, 56, 411-436. Kluwer Academic Publishers, Boston.

Taylor, J. A., 2008. Assessment in first year university: A model to manage transition. *Journal of University Teaching and Learning Practice*, 5(1).

Trees, A. R. and Jackson, M. H., 2007. The learning environment in clicker classrooms: student processes of learning and involvement in large university-level courses using student response systems, *Learning, Media and Technology*, 32, 1, 21-40.

Todd, R. H., Magleby, S. P., and Parkinson, A. R., 2005. Experiences and Observations in Introducing Students to Design and Manufacturing Globalization. *Journal of Manufacturing Systems*, 24(3), 162.

Vera, C. Félez, J., Cobos, J.A., Sánchez-Naranjo, M.J. and Pinto, G., 2006. Experiences in education innovation: developing tools in support of active learning. *European Journal of Engineering Education*, 31, 227–236.

Table 1. Survey questions relating to the students' perceptions of how useful they found the quizzes and corresponding student responses (N=59).

	Mean	SD
1. Did you find the quizzes to be useful activities?	4.61	0.48
2. Did the quizzes help you to improve your understanding of the course materials?	4.39	0.57
3. Did participation in the summary quizzes improve your exam preparation when compared to other courses?	4.30	0.54
4. Did the quizzes help to improve your interest in the subject area (Foundation Design)?	3.96	0.62

SD = standard deviation
N = number of student responses

Table 2. Survey questions measuring the students' participation and interaction during the quizzes and corresponding student responses (N=59).

	Mean	SD
5. Did the quizzes encourage you to participate more in class?	4.30	0.62
6. During the quizzes how much interaction did you have with your peers?*	4.78	0.56

SD = standard deviation

N = number of student responses

*Note: Question 5 is based on a slightly different scale to the other questions, in this case: 1= No interaction, 5= A lot of interaction

Table 3. Additional survey questions and corresponding student responses (N=59).

	Mean	SD
7. How did you find the level of difficulty of the quizzes?*	3.26	0.40
8. Would you recommend that the summary quizzes are used again next year?	4.78	0.41

SD = standard deviation

N = number of student responses

*Note: Question 7 is based on the different scale to the other questions, in this case: 1= Much too easy, 3= Just Right and 5 = Much too difficult

Table 4. Final summative examination results with: (a) quizzes incorporated in the course, and (b) the previous year's course where quizzes were not included.

	Mean (%)	SD	1st Class Honours (%)	Failure Rate (%)
a. Course incorporating ARS summary quizzes (N=71)	60.22	13.27	23.1	7.7
b. Previous year without ARS summary quizzes (N=70)	52.53	13.08	8.5	14.1

SD = standard deviation

N = number of students sitting the examination

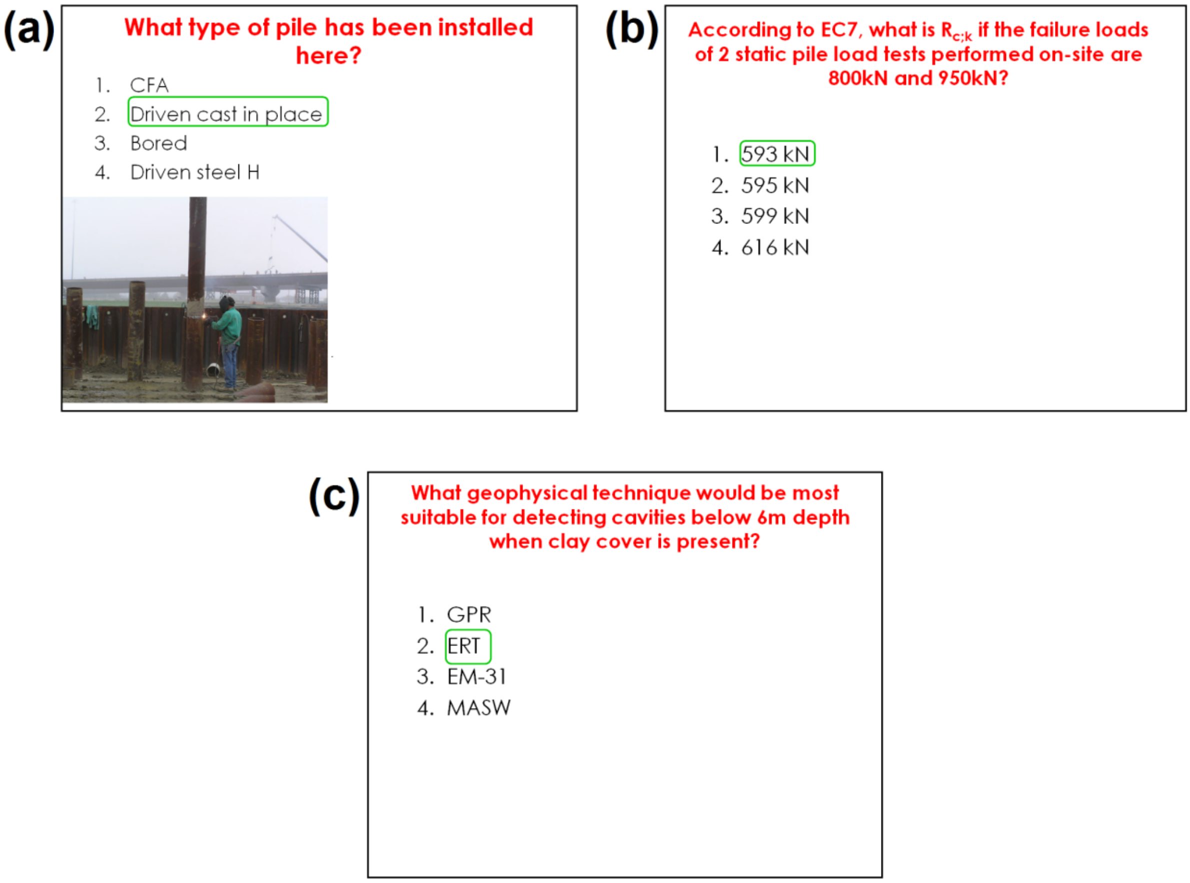

Figure 1. (a) An example of an easy question, in this case the correct answer (highlighted by a rectangle) is relatively obvious from an inspection of the visual image and a process of elimination of the incorrect answers. (b) An example of an intermediate level question, where an incorrect answer (595 kN) could be selected if the correct procedure is not followed carefully. (c) An example of a more difficult question, where three of the answers provided are plausible, as GPR, ERT and EM-31 may all be used to identify cavities under certain situations. In this case, however, GPR may be unsuccessful due to the conductive clay cover and the EM-31 method has a depth of penetration of around 6m, thereby leaving the ERT method as the most suitable approach.